Choosing Correct Forensic Marker(s) in Currency, Document and Product Protection

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ABSTRACT

The use of forensic markers (often known as 'tags' or taggants) as authenticity agents in currency, document and product provenance protection is gaining increased acceptance. There is now a wide choice to be made from a variety of technologies available from a number of suppliers. What criteria should be employed to aid the selection of the most appropriate technology? This paper will identify by type the range of technologies available.

The use of tags and identification markers in all forms of authenticity test is highly dependent upon criteria such as the method used to deliver the marking component and the equipment needed to identify and extract the marking agent during the authorisation process.

For instance, the type of marking system that can be effectively used in currency protection will require different attributes to that of a marker that identifies the authenticity of say a pharmaceutical product or the provenance of a precious stone.

Such marking systems offer quality results to potential users, all of whom posses their own distinctive needs. However the correct choice will be driven by a decision making process that involves cost, speed of application, ease of recovery and low risk of compromise as well suitability for purpose.

This paper will briefly identify the way forensic markers can be utilised in protecting users from various risks such as counterfeiting, dilution and refilling. This paper will also explore the technical aspects of each process with regard to characteristics and components involved in the system and then analyse the suitability of a range of available technologies to address risks on a sector by sector basis.

Keywords: Taggants, tags, microtaggants, markers, forensic markers, authentication markers, molecular markers

1. INTRODUCTION

Established practice in the authentication of currency, documents and products calls for a 'tiered' approach that addresses primary features such as holograms, secondary features (that require inspection tools) such as ultra violet inks and finally forensic features that can be used as irrefutable proof of authenticity should this be required by say a Court of Law. This proof is needed to support prosecution evidence in support of cases brought before the courts in relation to counterfeiting, forgery, product piracy and product dilution.

Criminals continue to copy and alter documents and counterfeit currency as well as replicating popular brands of consumer products that are sold to fund other crimes. Such crimes are complex by nature and it often becomes necessary to present expert testimony in such cases to establish guilty or innocent verdicts.

In some instances however it may only be necessary to identify that a fake exists. Such identification will set off other processes that may lead to prosecution evidence being required. (The discovery of counterfeit banknotes during processing will lead to withdrawal and enquiry about the source).

The use of forensic markers that can be embedded in products and packaging (and later identified as authentic) is now an important part of the strategy and tactics deployed in fighting crimes involving piracy, counterfeiting and forgery.

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2. Types of Forensic Marker

2.1 Historical background

Taggants are effectively miniature molecular or microscopic level data-carrying name platelets that can provide a positive indication about a product batch and / or manufacturing source.

Such products can be embedded into document substrates such as paper in the case of documents and labels, or into inks in the case of currency protection. Where there is a threat from dilution attack which happens in the petroleum product marketplace as well as agricultural chemicals, such markers are useful in establishing the levels of dilution too since they are added to such products in exact proportions and any reduction in such levels is measurable by hand held analysing equipment or under laboratory conditions.

Fibres, Star Lites and Planchettes (the earliest type of taggant – some decades old) are used in papers whilst molecular markers like biological codes and synthetic DNA tracers are used in liquids and powders. The latter have only become widely used in the last decade or so since the emergence of highly sensitive sampling equipment.

Fibres in coloured or UV form are added to the pulp before paper manufacture. Length and frequency of distribution can be controlled in the papermaking process hence each batch can be made uniquely. Star Lites are microscopic UV brightened particles distributed within the paper sheet and visible under UV light. Planchettes are small, coloured polyester disks that can be inlayed into the paper surface by random distribution during the papermaking process. Such Planchettes can be made from UV sensitive or optically variable materials.

More recently nanotechnology has delivered a variety of new, improved devices - in particle form - that can be engineered almost at molecular levels and can be identified by a variety of proprietary techniques.

A wide range of taggants (as they are called) are available that can test for dilution as well as replication attacks. Such taggants can be applied on labels / packaging, or incorporated into a product. Taggants are in effect microscopic 'markers' that are placed on, or in, the product at pre-determined levels that allow the user to 'test' for their presence later on down the supply chain.

A degree of operator intervention is required to extract the taggants. So a microscope, spectral illumination, radiation measurement or testing kits are needed to detect their presence.

Broadly speaking there are five / six specific varieties of Tags and Taggants:

- Organic Molecular Markers
- Inorganic Molecular Markers
- Miniature Nameplates
- Radioactive Tracers
- Nanotechnologies / Nano-Coating Particles.

2.2 Organic Molecular Markers

One of the most well known organic molecular marker systems is a biological code, which is widely considered to be one of the most powerful coding systems for liquids. This is because some liquids such as drinks are consumed by people and as such the marker – if placed in the product must be safe and at such a low a level that it does not affect the taste of the product. Biological taggants are based on selected plant enzymes and molecular structures that can be quickly identified by a specific chemical test. Because there are a multitude of such biological markers that can be used, it is easy to identify and allocate specific engineered markers to individual uses such as protecting one type of product label[1,2] or the ink used on a passport visa page.

The taggants are engineered and then placed into the product or document substrate in a form that is entirely covert and without prior knowledge it is not possible for outsiders to identify their presence or their composition.

Biological coding systems have some established testing methods:

- A wet stick method with chemical reagents (similar in operation to a pregnancy tester).
- A more accurate field testing kit that involves precise sampling to establish dilution.
- Final laboratory analysis that can be used in legal process.

Other organic marking systems are available that carry specially formulated organic tags that are dissolved into ultra violet fluorescing microscopic beads. Such beads are inert and are only used to carry the marker[3].

In this case, the beads are embedded into the product or coated onto the product or packaging using spray systems. The beads can be identified under magnification (and UV light) and extracted later for analysis. Laboratory systems are required to identify the tag extracted and this is identified and used to confirm authenticity. Such systems are used to protect and identify precious stones and in some cases heavy oil products used for marine fuels, the extracted markers being used to identify instances of marine pollution.

Other biological markers are diluted in purified water and sprayed onto selected areas of large products such as heavy engineering equipment so that it can be identified if it is stolen.

Again these products rely on specific narrow band UV brighteners to disclose their presence. Specially created organic markers are dissolved in an inert spray that is applied to coat the entire product thus protecting its ownership or authenticity. Whilst these are widely used in theft prevention/detection systems they also have relevance in establishing the authenticity of a document or a label.

Systems have also evolved that are based on proprietary plant DNA encapsulation processes[4,5]. Embedded DNA, placed in micro-capsules (similar to those used in paper copy transfer media) can be authenticated by using an instant 'developer' carried in a special (felt tip pen applied) ink.

By tailoring the DNA to suit client applications a unique solution can be applied to each and every problem encountered.

The use of such DNA product was selected by the US Commerce department in April 2003 as an embedded textile marker to identify textiles originating in the domestic US market.

The product can also be applied to garment labels and hand tags to identify original branded finished clothing. Other applications include the protection of microchips in financial and ID cards.

Apart from the textile verification process that embeds the micro-capsules into the cloth and requires a laboratory certification process, the most useful part of the system is the instant authentication of DNA codes carried in inks and coatings applied to labels and tags.

When these inks and coatings are subjected to a 'developer' chemical applied to a protected printing ink a reversible colour change takes place in 5 to 10 seconds. Since only one specific area of ink needs to be subjected to any test (and this is kept confidential) the process is rapid and very cost effective.

DNA coding is also kept confidential and specific to each client application. Because the codes are difficult to reverse engineer it is seen as an ideal solution to brand protection applications.

A further benefit of such biological markers is that they can be used to protect ink jet applied codes since the organic molecules are small enough to be used in these delivery systems.

2.2 Inorganic Molecular Markers

As the name implies inorganic molecular markers of this type are produced from specific inorganic substances that can be specially manufactured under controlled conditions and identified later with proprietary technology. These markers mostly involve the creation of specially made/modified molecules or mixed rare earth elements made into non-natural compounds. These molecules or elements can subsequently be extracted (or identified) from samples taken from the ink in the case of banknotes and labels/packaging in the case of products and then analysed / identified by their molecular weight / spectral signature.

Such techniques require analytical equipment that relies on the spectroscopic breakdown and display of relevant data which is compared to 'look up' tables.

Some proprietary systems work in conjunction with hand held readers that identify specific colour changes as they take place and then report on the status of such a change through a series of 'go' 'no go' indicators built into the reader.

Most of these systems are highly proprietary and because they are utilised in currency authentication little is publicly known about the chemicals or validation processes involved other than they depend upon testing with specific inspection equipment that provides an indication of the presence (or absence) of the proprietary marker concerned.

A disadvantage of such inorganic systems is that they cannot be used as markers in food products (for safety reasons) or in ink jet delivered codes since the grain structure of the pigment substances used can block print heads.

Careful selection of inorganic markers is required so as to ensure that the optical properties of inks is not affected by the inclusion of such components.

2.3 Miniature Barcodes

Since the early 1970's, barcodes have been used by companies worldwide to streamline data collection and identification, and to create more efficient systems for tracking, taking inventory, and validating identification.

Barcodes contain an identification number capable of being read automatically and link an item to a database with all the relevant information about where the item was made and/or what has happened to it as it passed along the manufacturing/supply/use chain.

They cannot however be used as indicators of authentication since they can be copied in traditional form. Miniature bar codes have been developed that can be embedded into products and inks that can be used to identify the provenance of the substance[6]. A variety of systems exist that include microdots and miniature nameplates that involved encoding nano-printed identifying marks that can only be viewed through a high power microscope[7-8]. An example of a commercial name is datadot (www.datadotdna.com/).

These codes are placed upon the carrier substrate which can be polyester or metalised foil with a high resolution laser scribing process. Taggants of this variety are small but still much larger than molecular in size and as such have to be mixed into a viscous carrier such as a varnish or ink. They benefit from the fact that they can be recognised easily without the need for specialist training and/or equipment.

A good illustration of this technology is found in a range of products that consist of minute grains of multilayered coatings. The products can be created by spraying coat upon coat of different coloured inert compounds on top of each other. The final ‘sheet’ is crumpled and granulated creating a fine dust consisting of multi-layered particles or platelets. Examples of commercial names of such multilayered microtags are Microtaggant® (see Figure 1) and Secutag® (see Figure 2). The various layers create a unique coloured display code that can be used as positive identification of an application[9]. The multi-layered particles can be magnetised thus making extraction easier.

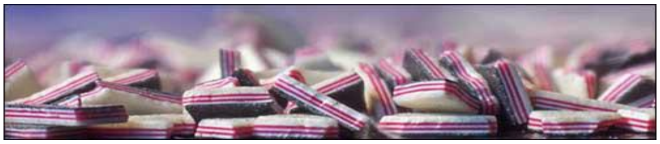

Figure 1: Layered microtags – Microtaggant® identification particles from Microtrace. The layers are alternately coloured red and white.

From: http://www.microtaggant.com/microtaggant.htm.

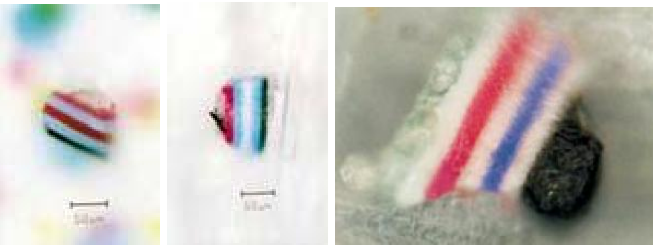

Figure 2: Layered microtags – Identification particles from Secutag®. The layers have various colours: red, blue, green and white.

From: http://www.secutag.com/.

The particles can also be UV reactive thus making visual identification easier (this is provided that the marker is used in or on an optically dull product). Markers of this type are used to identify batches and distribution of explosives. They are highly resilient and extracts of such markers after terrorist attacks can help trace the perpetrators. (The Oklahoma Bomber was traced using this technology).

Another process involves the production of nano-barcode particles, which possess several characteristics that make them ideal for incorporation into auto-ID technologies, and for use in tagging objects where conventional bar coding is not applicable[10-12].

Figure 3 shows a nano-barcode that can be optically resolved through a low power microscope. Once this task has been completed the particle can be automatically authenticated through a computerised recognition process. Different combinations of metallic coatings and lengths provide a wide variety of specific coding structures that can be utilised by licensed clients. For instance, figure 1 shows microscopic coatings of silver (Ag) and gold (Au) applied in sequence to a nano-barcode (NBC) for identification purposes.

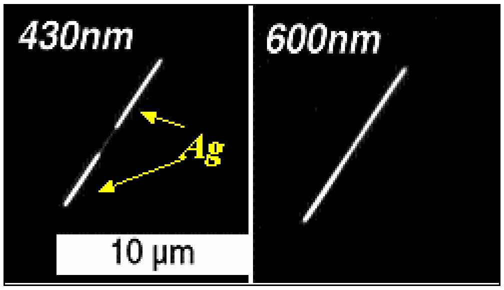

Figure 3: Differences in reflectivity at 430 nm versus 600 nm for nano-barcode sequence Ag-Au-Ag. From NanoPlex Technologies[11].

The low cost of manufacture of nano-barcodes, ease of application and retrieval, ability to be created in billions of unique combinations, and nano-scale size make them ideal for creating low cost, nano-scale tags for small, mass produced items.

Illustrations would include use as tags for fasteners or screws used in aircraft construction or other complex machinery, computer microchips and the like (where size restricts the use of conventional tags).

Nano-barcode particles are also well suited to tracking items that are exposed to the environment for long periods of time—they can be made from oxidatively inert elements such as platinum and gold, and since they are magnetic, they can be retrieved and identified even from extremely large volumes of material.

2.4 Radioactive Tracers

Radioactive isotopes are also used as taggants even though these tags may only display very low level radioactivity they are able to identify traces of taggant even at molecular levels. Such radioactive taggants are not considered suitable for marking products that are ingested, such as drinks, foodstuffs and pharmaceuticals or even products that come into contact with human beings, such as toiletries and cosmetics because of the negative image radioactivity projects. Such taggants can, however, be effective as markers in fuels and mechanical parts.

Whilst it is understood that radioactive tracers are used for medical applications such as monitoring drug delivery where exposure to radioactivity is controlled and relatively brief, prolonged exposure through product contact in production processes is impractical.

There has been an understandable reluctance to use some of the radioactive markers that are available in the marketplace. Crystal Tag (produced for the US Government by the DOD) was one notable exception to this. These tags were developed as part of the nuclear weapons decommissioning program in the 1990's and used to identify 'counted' components and complete systems so that they could not be accidentally or deliberately double counted (which has the risk of leaving some systems still available for use, by unauthorised parties). Apart from this single outstanding military application the system has found no other known use.

The disadvantage of radioactive tracers is not just one of health concerns. The analytical processes involved in the identification and extraction of the marker can only be carried out using suitably trained personnel and the right equipment.

2.5 Nanotechnologies / Nano-Coatings

Nanotechnology is a relatively new field where products such as high specification lubricants and micro bearings are being manufactured for use in nano-machinery. Such nanomachines are expected to provide medical benefits in future as they are being engineered to deliver drugs more rapidly and accurately to specifically targeted areas of the body.

In military applications micro machines will be used to miniaturise weapon delivery and reconnaissance systems.

As a by-product of the R & D in this area, the development of micro (and sub-micro) specially engineered tracers has led to various 'super small' tagging processes that are suitable for product authentication.

Whilst nano-coding or nano-dimensional materials consist of a variety of specifically engineered (rather than naturally formed) structures, all such nanotechnologies depend upon the engineering of micro-particles that are difficult to re-construct (hence provide anti-counterfeit resilience). Such products are often proprietary (can be patented and protected). However some inventors prefer not to expose their methods to patent protection for fear of making their work too public.

Tags developed also need to be easy to verify and as we have seen from the application of a variety of DNA type taggants they must be robust enough to withstand ageing as well as application methods and exposure to decay mechanisms that they may come into contact with during lifetime use.

A recent entrant to this field is 'Quantum Dot' technology. Quantum Dot 'nano-particles' are so small that many more of their atoms are on their surface rather than at their core. Their physical behaviour is governed by quantum physics – hence the name 'Quantum Dots'. Quantum dots can be used as fluorescent taggants, which add a unique optical signature to security inks, papers, plastics, explosives, or any other article or material. The optical uniqueness of quantum dots is based on their specific spectral and temporal response, which distinguishes it from the response of any other luminescent substance that might be used by a counterfeiter in an attempt to achieve the same fluorescent properties[13].

The methods that have been developed utilise what is claimed to have minimal environmental impact and do not use hazardous chemicals.

The manufacturing process can be scaled up so that large quantities of nano-particles can manufactured. Particles are supplied in the form of dry powders, dissolved solvent or for long time storage in the form of a wax. At present it is not known how practical these processes are since the production of nano-materials has so far been marred by the fact that they are so small it takes a considerable amount of time and resource to produce enough quantity of product to be of use. An illustration of this is the carbon nano-tube business.

In the same way that nano-particles can be used for product protection nano-defects in surfaces can be useful if they can be indexed and referenced using the right equipment. Even so new instances of authentication devices delivered at such a nano level are still fairly rare.

Universities are experimenting with new techniques that stretch the envelope further and provide more choice for users who have more specific applications and where currently developed solutions are inappropriate. One such system is a security code based on nano-technology originally developed at Durham University in the United Kingdom that offers applications in document or item protection against unauthorised replication[14,15]. The system relies on the fact that almost all paper documents, plastic cards and product packaging contain a unique physical identity code formed from the microscopic structure of the surface. This microstructure is a unique material 'fingerprint' that cannot be controllably modified. It can be rapidly read using a low-cost portable laser scanner. The signal derived of the surface structure can be recorded but cannot be controlled or replicated. The laser scanned surface codes can be recorded in a database, which allows retrospective identification of the product or document through a look-up system, using the original code as a reference, in order to compare the nano surface characteristics to those stored in memory. The database reconciliation process is fairly quick, taking around 10 seconds plus 3 seconds for the initial code acquisition. It is expected that most forms of document and branded-product fraud could be rendered obsolete by use of this code[15].

3. APPLICATIONS

3.1 'Horses for Courses'

Since there are now established ranges of technologies and a variety of suppliers servicing the forensic marker marketplace it would be useful to analyse the likely uses for such taggants.

3.2 Tags to authenticate items (products)

This not as straightforward a task as it may at first seem. Since most products will carry a label or be placed into packaging, establishing the authenticity of the containers can be achieved by including a marker in the packaging material or the printing ink. However refilling may be a problem too and thought has to be given to checking the contents of the pack as well as the container.

In cases such as these then biological coding systems offer the most effective solution since similar markers can be used in both instances and these can be compared during analysis to indicate authenticity.

Where large products are involved such as engineering equipment and machinery then systems that provide complete coating solutions may be necessary or the use of discretely placed miniature nameplates may be a more cost effective option.

3.3 Tags to authenticate materials (papers, inks and boards)

Consideration needs to be given to systems that allow substrate checks to be carried out. In the case of papers then synthetic tracers can be added to the pulp during the manufacturing process, but with inks and varnishes it is more practical to add inorganic molecular markers since these can be identified with hand held readers.

Applications would include travel tickets and lottery tokens and well as vouchers and other documents of value such as cheques and tax stamps. Other uses would include the checking procedures associated with travel documents such as passports and visa labels or stamps.

In such instances these tags offer a versatile secondary authentication feature that can complement the type of inspection system employed in financial and travel systems to identify fake documents.

3.4 Tags to authenticate data (toner and other non impact data applications)

It is often useful to be able to identify ink and toner used to add variable data to documents and labels. Such systems would include non-impact printing from ink jet systems as well as toner-based printing machinery.

There are a number of reasons for establishing the authenticity of inks and toners. Firstly the manufacturers of such products are keen to identify pirate copies and refilled cartridges and secondly it is a useful check to ensure alteration has not taken place to variable data placed on documents of value. For instance in cheque applications it may be necessary to establish that the original toner has been removed and replaced with other data to substantiate a fraud.

In these examples consideration needs to be given to the ability of the chosen technology to deliver the solution through the chosen print method. Ink jet system manufacturers supply either solvent based or water based inks. Since both are designed to address specific applications it is important to understand the constraints of each technology.

Inorganic taggants work best in solvent based delivery systems since the pigments and tags used are easily dissolved. Organic pigments are more suitable for water based inks, because such delicate organic taggants may be destroyed or compromised by the heat delivered in toner based printers. In this case more resilient inorganic compounds are called for.

Applications for such technology would be the toners and ink jet inks used across a variety of uses to add code lines and protect messages placed on product such as use by dates and manufacturers track and trace information.

3.5 Tags that provide discrete and instant authentication with hand held devices

Instant validation of forensic tags is a relatively recent development. Previously users have had to wait for laboratory tests to identify taggants. This is still the case when trying to identify certain dilution attacks but several suppliers offer readers or developing kits that can provide instant confirmation that a specific tag is (or is not) present.

Most systems depend upon discrete hand held battery powered readers that provide an instant audible or visual message confirming that a tag is present. These are particularly suitable in travel systems to validate tickets and seasonal passes. These tags are based on inorganic markers and some work with hand held laser pens that provide a visual colour change when the ink carrying the marking agent is illuminated.

There are also choices that can be made that include wet ink marker pens and hand held developing kits. Some of these systems are re-usable since once developed (using wet chemistry) the marking agent dries later and can be re-activated if required.

3.6 Tags that can only be identified under laboratory conditions

There are products that cannot be effectively tested in the field and therefore require laboratory conditions to be present for analysis. For instance if legal evidence is gathered and is to be used in Court it is necessary to ensure that expert witness statements supporting that evidence are given[16, 17]. It follows that a Court is likely to give more consideration to evidence gathered and supported by laboratory tests that through alternative sources.

Small items such as precious stones can be marked with specific tags that can be recovered in the laboratory to prove ownership or define provenance. It may also be necessary to analyse medical and pharmaceutical products under such conditions.

3.7 Tags that provide continuous (fast) authentication in machine sorting and verification systems

In currency authentication it is necessary to establish the validity of banknotes on a regular basis. Many primary identification features provide provenance checks for the public and for banking counter staff – these include watermarks and holograms. However when high speed sorting and cash handling machines are employed, a fast and reliable system of confirmation is required. Forensic tags are ideal for this purpose since their presence can be quickly established through electro-mechanical authentication devices.

The phosphor coating placed on postage stamps is a traditional illustration of this technology. The technique depends upon the excitation and time taken for a phosphorescent signature to decay. In high security applications such as currency verification more confidential methods are needed.

Similarly the verification of banknotes offered to public vending systems calls for novel tags as authentication devices. Often these will differ for reasons of security to the taggants used in main-stream banking systems. Therefore it is possible that most currency carries at least two variations of forensic marker.

3.8 Tags that can be embedded in liquid products

The tags employed to identify liquid products are used to establish authenticity as well as purity (i.e. the product has not been diluted or substituted). It follows that only taggants that are completely dissolvable are suitable for such applications.

Such tags are useful to identify specific attacks such as the counterfeiting of liquor or substitution of agro-chemicals. The additives used to enhance the performance of carbon fuels are a further illustration. Such additives are placed in fuels to ensure a leaner burn or maybe provide special lubrication properties. In some parts of the world cheaper varieties of fuel oils are substituted for popular brands that command a higher price. Brand Owners need to be able to test for this risk.

Likewise suppliers of concentrated liquid products that are diluted before use also need protection from attack. Applications include chemicals and soft drink syrups. However in some cases drink purity laws forbid the inclusion of any 'foreign' product. Scottish Whisky is the best example of this.

3.9 Tags that can be embedded in powder or granular products

Since these items are manufactured and shipped in bulk they need to be treated with taggants that are adaptable and suitable as marking agents. For instance granular coded products are not suitable for marking hybrid seeds that require a coating to be applied. Since water based coatings may start or affect germination careful consideration is necessary before choosing the appropriate delivery mechanism.

Similar conditions apply to powder products where 'caking' would affect their performance. Specialist granular feed stocks such as those used in the plastics industry are a good example of a product that would require specific attention.

3.10 Tags that can be 'engineered' to specific client profiles

Forensic marking systems that are infinitely adaptable will gain more favour than those that are limited by the number of variations possible. For these reasons synthetic DNA and combinations of rare earth man made compounds offer the widest variety of combinations that allow each and every client access to any number of unique tags that can be applied to a whole range of problems. For instance in the UK a National Security Register of such forensic markers is held by Smartwater a company that specialises in forensic coding systems (http://www.smartwater.com/news/fom.html#safe). Each user and each application are registered on the database and this provides a central point from which information can flow when identification and analytical tests are required. When stolen goods are recovered they can be returned to their owner.

4. SUMMARY

Nanotechnology is a very new and exciting field that will provide a rich source of authentication technologies for future use. Forensic markers have acquired an important place in security printing as a method of establishing authenticity and as an anti-forgery device. Such markers are invaluable in identifying dilution attacks and as a means of ensuring that products are original and not fakes.

Science is constantly delivering new and alternative methods for marking the provenance of currency, documents, consumer and industrial products. As these choices increase, careful thought needs to be employed before selecting the most suitable and appropriate solution to the identified problem.

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